Examination of Pig Farm Technology by Computer Simulation

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Abstract: Agricultural production is among the riskiest production activities. Similarly to other branches of agriculture in animal breeding the finished product is the result of complex procedures. The biological-technological procedure, the creation of the product is affected by an outstanding number of environmental factors which also cause uncertainties.

In the North Great Plain Region of Hungary, sows, gilts and slaughter pigs are produced on a corporate farm. The reliable operation data of this company provide a stable basis for and estimating future costs and revenue and their distributions.

Monte Carlo methods are one of the generally accepted tools for modeling risks. The significant independent variables, their ranges and probability distributions, and the correlation between them were inputs to the model. The values of the variables were produced using a random number generator. The computer simulation was performed using @Risk (Palisade Corporation) software. The study concentrates on the factors affecting the number of offspring (piglets). Model inputs were the mating, mortality and farrowing rates; the costs and the income values based on these rates have been analysed as the output data of the model.

1. Introduction

At the time investment decisions are made, agricultural producers cannot know how external and internal factors will influence the outcome of their decisions (*Bácskai et al., 1976; Hardaker et al., 1997; Drimba,* 1998a). Important decisions influencing the future of the company have to be made under conditions of risk, when reliable information is available only for the most recent time period. (*Buzás*, 2000). Risks are present in every economic sector and must be considered by every economic agent.

Economic agents should apply methods that are capable of measuring, monitoring and suggesting responses to risks, provided that the information required for decision-making is current and of sufficient amount and quality. The evaluation of this information should enable decision-makers to formulate and analyze multiple decision alternatives.

When sufficient data is available, there are numerous statistical analyses for measuring risk. Risk management tools, often tailored to evaluate specific types of risk and provide a variety of metrics, provide users with accurate measurements and allowed them to make informed decisions regarding alternative courses of action. Risk evaualtion has been an increasingly important component of economic analysis over the past ninety years, with applications to and significant results for every sector of the economy, including agriculture. Developments in information technology and of the Internet have facilitied the development of applied risk management tools, which have become affordable for even the smallest of enterprises and easy to use.

New, complex and wide-ranging types of risk have arisen, the measurement of which requires sophisticated mathematical and financial models. The development of computers has supported the development of these models, which can evaluate risks considerably support the faster and more accurate determination, measurement and handling of risks (*Beaver – Parker*, 1995). Simulation models, whose use in agriculture has grown rapidly, attempt to mimic the operation of real systems so as to allow accurate measurement of uncertainty and risk.

The study was based on data from HAGE Ltd.'s 1100-swine farm at Mezőhegyes. Our aims were to study the operation and expected results of the farm's operation in 2009.

2. Materials and methods

Simulation models are the simplified mathematical representations of real systems for studying their behaviour under different conditions and varied circumstances. In contrast to the point estimates provided by other analytic methods, these methods require multiple implementations of

the model in order to determine representative samples of performance indicators for describing the operation of the system (*Winston*, 1997). Simulation models are designed to consider randomness; stochastic simulations using Monte Carlo methods are a generally accepted tool for evaluating system performance and associated risks. Values are randomly drawn from probability distributions of independent variables in order to develop distributions for desired performance metrics. (*Russel-Taylor*, 1998).

Models for analysis specify the set of variables that influence outcomes, their potential range, probability distributions and correlations. Given the ranges and distributions, the values of the variables are produced using a random number generator. The model is run 1,000–10,000 times and an expected value and a range of values are obtained for the desired result variable. These values can then be used to determine the probability that its value will fall into a given interval (*Winston* 2006, *Ertsey* et al. 2008).

A frequent output of simulation models as applied to firm operation is revenue; the metric of interest is the probability of exceeding or falling short of a given value. By increasing the number of runs, the distributions of result variables can be derived with arbitrary accuracy, as follows (1) (*Watson, 1981; Jorgensen*, 2000):

$$\psi = E_\pi \{U(X)\} = \int U(x)\pi(x)dx, \qquad (1)$$

where $X=\{\theta, \phi\}$ a θ is a vector including decision parameters, ϕ state parameters and π denotes the distribution of x. U(x) is a utility function usually expressing revenue, the function E π() gives the expected utility under the given distribution. An advantage of the method is that the model can be run for separate decision variants and the risks of various decision variants can be compared. For the numerical determination of the above values the following formula (2) is used (*Jorgensen*, 2000):

$$\overline{\psi} = \frac{1}{k} \{U(x^{(1)}) + ... + U(x^{(k)})\}, \qquad (2)$$

where k represents the number of experiments, i.e. the number of runs.

Excellent, easily manageable simulation software is readily available; @Risk4.5 (Palisade Corporation) was used for this study. The model of the system is constructed in Excel (Microsoft); the user can select from several probability distributions and chooses the values of the parameters that characterize the distribution. The simulation runs provide the result variable, which is used to estimate the probability that it will take a value in a given interval (*Palisade*, 2005; *Winston*, 2001; *Drimba-Ertsey*, 2008).

In our study we applied the @Risk4.5 simulation software.

Introduction of the company

The headquarters of Mezőhegyesi Sertéstenyésztő és Értékesítő Ltd. is situated in Békés County. The company, whose primary activities are swine production and wholesale trading of agricultural products sales, was established in 1993. The company operates two swine farms: a 500-swine farm at Pereg, and an 1100-swine farm at Mezőhegyes.

The two farms jointly have the capacity for producing 35,000 porkers. Both farms raise Topigs, a breed that has excellent maternal inheritance, and therefore above average performance indicators (e.g.: animal yield, farrowing percentage) and piglet-rearing ability. For sow insemination, the company purchases boar semen from HAGE Ltd.'s Topigs boar farm.

The performance indicators of the farm at Mezőhegyes are presented in Table 1. The swines are fed with following feed concentrates: "Pregnant sow", "Suckling sow", "Sui-Fer", "Piglet", "Piglet I – II.", "Prestarter", "Fattening pig I-II.", and "Breeding store pig".

Model data:

Input data consisted of targeted calving rate, number of live birth piglets (animal yield), culling and emergency slaughter data, weight gain, the weight of purchased and bred gilts, and fixed and variable costs, notably fodder prices.

The inputs variables were considered random variables. The normal distribution was used to model biological indicators, and a triangular distribution was used to model fodder costs. Using a triangular distribution is a general practice when initial values, either minimal, maximal or the likeliest, are known. (*Evans* et al., 2000). A truncated normal distribution was used for the biological factors to prevent unrealistic values from being generated doing the simulation runs; 0.15 percent of the values were truncated from the upper and lower ends of the distribution. The triangular distribution used for fodder prices used the current price as the most likely value, with the minimum and maximum values equalling 95 percent and 150 percent of the current price, respectively. This was done to emphasize the likely increase of fodder prices rather than a decrease. Fodder prices were simulated assuming a high degree of correlation (0.9) as they are all similarly influenced by changes in crop prices. We assumed a weak negative correlation (r=–0.25) between weight gain and animal yield, and a weak positive correlation (r=0.25) between weight gain and mortality, because vividity is less at higher litter sizes.

Output data consisted of per unit revenue, per unit cost, per unit profit, per unit feed cost in relation to the total farm output. In addition, we take the total farm revenue, expenses and profit into consideration.

For the purposes of this study, 10 000 simulation runs were performed 10,000 simulation runs were performed, after which the sensitivities of per unit profit, per unit total cost, per unit variable cost and per unit fodder prices were examined. This analysis was based on standardized regression and Spearman's rank correlation coefficients (β). The standardized regression coefficient (β) indicates the influences of the explanatory (input) variables, and can be calculated if both the dependent variable and explanatory

Performance indicators of the pig farm			Applied intervals in the simulation
Number of farrowing / number of sows		2.41	2.30-2.46
Farrowing rate		89%	86%-92%
Animal yield (live birth piglet/farrowing)		11.9	10.95-12.85
Emergency slaughter rate of fattening pigs		1.0%	1.0%
Weight of purchased gilts (kg)		140	130-145
Weight of bred gilts (kg)		140	130-145
Culling rate	Suckling piglet	8.6%	8.17%-9.03%
	Brood sow	0.5%	0.475%-0.525%
	Battery pig	2%	1.9%-2.1%
	Fattening pig	3%	2.85-3.15
Weight gain (g/day)	Suckling piglet	260	234-286
	Battery pig	450	405-495
	Fattening pig	800	720-880
Specific Food Consumption Index (food consumption kg / weight gain kg)	Battery pig	1.72	1.72
	Fattening pig	2.80	2.80
	Farm level	2.82	2.82

variables are standardized (*Moksony*, 2006). The significance of the standardization lies in that the explanatory variables and the risk associated with them can be ranked independent of their unit of measurement (*Hajdu*, 2003). The sign of â shows the direction of the change: positive value indicates an increase in the value of the dependent variable if the explanatory variable's value increases, while a negative value indicates a decrease. In addition to the sensitivity analysis, we calculated the probability of the company's earning a loss in 2009, another risk metric frequently calculated (*Mun*, 2004).

3. Results and discussion

The results indicate that the fattening pig price has the greatest effect on per unit profit: a one unit change in the standard deviation of the price caused a 0.583 (β) change in the standard deviation of per unit profit. There is a modest correlation between the fattening pig price and per unit profit (Spearmann's rank correlation coefficient: ρ=0.585); the strongest correlation (–0.73≥ρ≥–0.76) is between the fodder prices and per unit profit; increases in fodder prices result in a decrease in per unit profit. Among the fodder prices, "Fattening pig I." has the most impact (β=0.198;); a one unit change in the standard deviation results in a 0.20 unit change in the standard deviation of the per unit profit in the opposite direction. The standardized regression coefficient was near zero (β<0.1) for every other variable *(Figure 1)*.

The per unit total cost is mainly determined by the "Fattening pig I–II." and "Piglet I–II." fodder prices. Among the farm performance indices the most influential factor is

the number of live birth piglets; the standardized regression coefficient was near zero (β<0.1) for all other variables. The sensitivity analysis revealed the same relationships between all the variables and the per unit profit or per unit total costs, although the signs of the standardized regression coefficients differ: increases in fodder prices increase the per unit total cost and decrease the per unit profit. The price of fattening pigs had no influence on the per unit total cost for obvious reasons; the variable is omitted from *figure 2.* in terms of the per unit variable costs, the values and rankings of the standardized regression coefficients differ only slightly from the results obtained from the analysis of the per unit total cost.

Taking the fodder costs into consideration, the regression coefficients for the most widely utilized fodders were between 0.160–0.246. The positive value indicates a definite increase in fodder costs. Changes in the price of "Fattening pig I." are the greatest source of fodder cost risk (|β| 0.246). Values for "Fattening pig I–II." and "Piglet I–II." ranged from 0.160–0.211. The standardized regression coefficient was almost zero (|β| <0.1) in the case of the other fodder cost variables *(Figure 3)*.

The 10,000 model runs yielded the distribution of the total cost presented in Figure 4. The mean is 905 million HUF, the lower and upper quartiles are 848 and 953 million HUF, and the distribution is right-skewed. Descriptive statistics are presented in *Table 2*.

Figure 5 presents the distribution of the total revenue of the swine farm. The mean value is 1005 million HUF, the lower and upper quartiles are 964 and 1045 million HUF, and the distribution is slightly left-skewed.

In case of the total profit, these statistical indices are as follows: the mean is 101 million HUF, the lower and upper
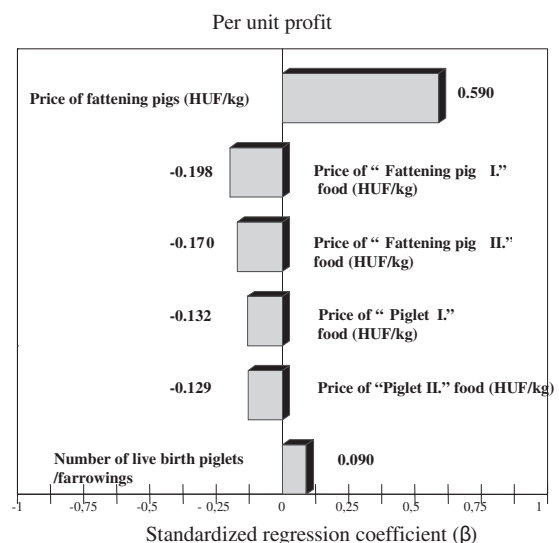

Figure 1: Tornado chart of the standardized regression coefficient pertaining to the per unit profit

Table 2: Statistical indices of the distribution of total cost, revenue and profit

Statistical indices	Total cost	Total revenue	Total profit
Minimum	756.766	828.774	-198.432
Mean	904.618	1005.123	100.505
Maximum	1141.625	1167.870	313.246
Standard Deviation	71.075	57.964	87.247
Variance	5051.685	3359.849	7612.086
Skewness (γ_1)	0.520	-0.147	-0.328
Kurtosis (γ_2)	2.544	2.577	2.668
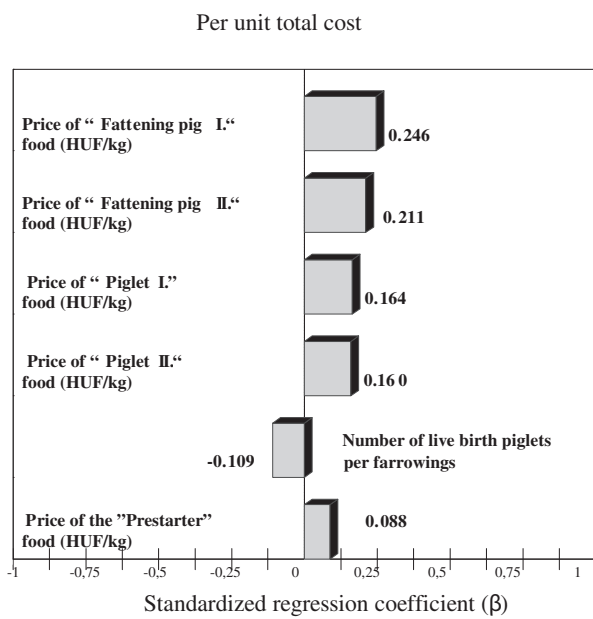
Per unit total cost

Figure 2: Tornado chart of the standardized regression coefficient pertaining to the per unit total cost
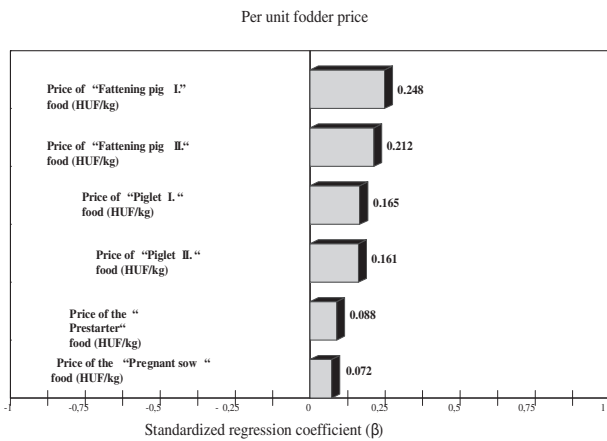
Per unit fodder price

Figure 3: Tornado chart of the standardized regression coefficient pertaining to the per unit fodder cost
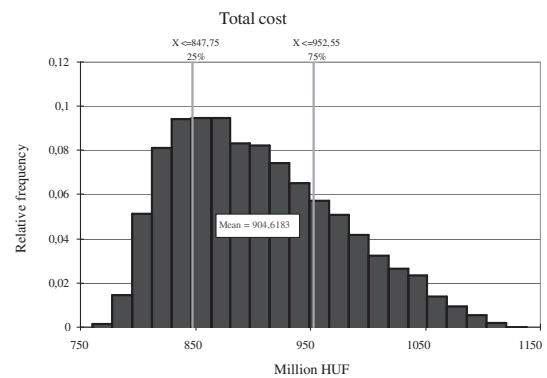

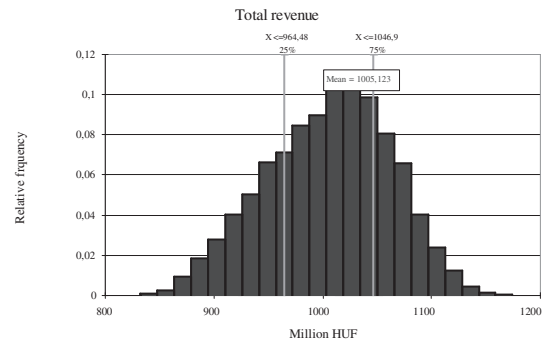***Figure 4:*** Relative frequencies of the total cost after 10.000 simulation runs

Figure 5: Relative frequencies of the total revenue after 10.000 simulation runs
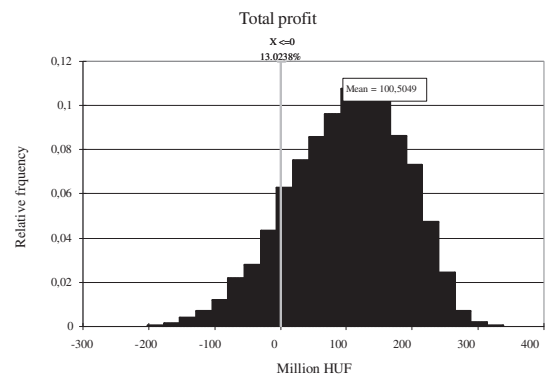

Figure 6: Relative frequencies of the total profit after 10.000 simulation runs

quartiles are 42 and 165 million HUF. The probability of the loss in farm's operation is 13.02 percent considering the above mentioned model settings *(Figure 6)*.

4. Conclusion

The primary determinants of swine production costs are fodder costs. During the past several years, enormous fluctuations in fodder prices contributed to a reduction in investment in swine production in Hungary, reducing output in the sector and threatening its future prospects.

In our study we used Monte Carlo simulation to model that the stock changes in a Hungarian farm and determine the factors that have the largest influence on profit and costs. Input and output prices and the major performance indices were the (random) variables considered.

Our results indicate that changes in per unit profit are influenced most by the price of fattening pigs as indicated by the relative magnitude of the regression coefficient (β =0.59)

Among the fodder prices, only "Fattening pig I–II." had an significant effect on per unit revenue, costs, profit, and fodder costs. These two fodders constitute most of the annual fodder purchases and farm costs. The standardized regression coefficient was nearly zero ($\beta<0.1$) "Prestarter", "Pregnant sow", "Suckling sow", "Piglet", "Breeding store pig" fodders.

While simulation techniques provide insight as to the operation of economic systems, they necessarily entail simplification; the system as modelled is less complex that that whose performance it attempts to reproduce. It is axiomatic that this reduction in complexity introduces errors, whose magnitude depends upon both the model chosen and the variables it considers; these errors are the inevitable result of simplified mathematical representation of real systems.

References

Bácskai, T. – Huszti, E. – Meszéna, GY. – Miko, GY. – Szép, J. (1976): A gazdasági kockázat mérésének eszközei. Közgazdasági és Jogi Könyvkiadó, Budapest

Beaver, W. H. – Parker, G. (1995): Risk Management: Problems and Solutions. – Stanford University. p. 1–17.

Buzás, Gy. (2000): A gazdasági kockázat kezelése, biztosítás In: Mezőgazdasági üzemtan I. In: **Buzás Gy. – Nemessályi Zs. –**

Székely Cs., Mezőgazdasági Szaktudás Kiadó, Budapest, 434–457.p

Drimba, P. – Ertsey, I. (2008): Elméleti és módszertani alapok. A kockázat forrásai, kockázatelemzési és becslési módszerek. in: Hatékonyság a mezőgazdaságban (Elmélet és gyakorlat) szerk.: Szűcs I. – Farkasné F. M., Agroinform Kiadó, Budapest 280–295. p. ISBN 978-963-502-889-4

Drimba, P. (1998a): A kockázat figyelembe vétele a mezőgazdasági döntési modellekben. PhD értkezés, Debrecen

Ertsey, I. – Kovács, S. – Csipkés, M. – Nagy, L. (2008): Malomipari beruházások kockázat- és gazdaságossági vizsgálata Magyarországon. Hagyományok és új kihívások a menedzsmentben". Nemzetközi Konferencia, Debrecen, 5 o.

Evans, M., Hastings, N., and Peacock, B. (2000): Triangular Distribution. In Statistical Distributions, 3rd ed. New York: Wiley, pp. 187–188.

Hajdu O. (2003): Többváltozós statisztikai számítások. Központi Statisztikai Hivatal. p. 215. ISBN 963-215-600-5

Hardaker, J.B. – Huirne, R.B.M. – Anderson, J.R. (1997): Coping with Risk in Agriculture. CAB International, New York

Jorgensen, E. (2000): Monte Carlo simulation models: Sampling from the joint distribution of "State of Nature"-parameters. In: Van der Fels-Klerx, I.; Mourits, M. (eds). Proceedings of the Symposium on "Economic modelling of Animal Health and Farm Management", Farm Management Group, Dept. of Social Sciences, Wageningen University, p. 73–84.

Moksony F. (2006): Gondolatok és adatok. Társadalomtudományi elméletek empirikus ellenőrzése. Aula Kiadó 205. p. ISBN 978-963-200-100-5.

Mun, J. (2004): Applied risk analysis. John Wiley&Sons, Inc., p. 91-94..

Palisade (2005): @RISK advanced risk analysis for spreadsheets. Version 4.5. Palisade Corporation 22, 116, p.

Russel, R. S. – Taylor, B. W. (1998): Operations Management, Focusing on quality and competitiveness, New Jersey: Prentice Hall, p. 610-613.,

Vose, D. (2006): Risk analysis. John Wiley&Sons Ltd. p. 418.

Watson, H. (1981): Computer Simulation in Business. New York: Whiley

Winston W. L. (1997): Operations Research Applications and Algorithms, Wadswoth Publishing Company, 863–870.

Winston, W. L. (2001): Financial modells using simulation simulation and optimization. Newfield. Palisade Corporation. p. 379.

Winston, W. L.: (2006): Financial modells using simulation simulation and optimization. Newfield. Palisade Corporation. p. 505.